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ACO-GA Algorithm in Global Path Planning of Mobile Robot

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ABSTRACT

Mobile robot path planning in both static and dynamic environments is a challenging topic in the field of robotics. In order to avoid the obstacles and minimum time period to reach the goal in environments, different methods have been implemented by

researchers and continuation of researches in the above said field. In this paper, we have proposed a hybrid Ant Colony Optimization (ACO) - Genetic Algorithm (GA) method in path planning of mobile robot to give the efficient optimized path and novelty from the existing methods applied till now. We have compared our proposed method with the two state-of-arts methods, i.e., ant colony optimization, genetic algorithm, and simulation results shows that the proposed method is more outperformed than the others.

Keywords: Mobile Robot, Path Planning, Ant Colony Optimization, Genetic Algorithms

1. INTRODUCTION

Mobile robot path planning is the important application in the field of robotics. Two important features the algorithm are known and unknown environments, i.e, static and dynamic environment. In static environment, the obstacles coordinates are known whereas in dynamic environment the obstacles coordinates are not known before the path planning. In path planning problem, the categories of the path planning is divided into global path planning and local path planning. The first categories, robot has a prior knowledge about the environment modeled as a map and the path can be planned offline based on the available map. The second categories, robot does not have the prior knowledge of the environment. Thus, it has to sense the location of the obstacles and construct an estimated map of the environment to avoid the obstacles and to get a suitable path towards the goal state. Our re-search focused on the global path planning. Many Heuristic methods are implemented to solve the problem of path planning which some of them are artificial neural network (ANN), genetic algorithm (GA), ant colony optimization (ACO), particle swarm optimization (PSO). These methods are the main motivation of this paper. In this paper we have implemented ACO method to find the path and GA to optimize the optimal path. Mobile robot motion problem is controlled by neural networks-based techniques which it first used to find the free space and secondly find the safe direction while avoiding the nearest obstacles in environment [1]. A near optimal in path length of mobile robot and the speed is fast in complex environment which is proposed in [2]. Optimized path length with minimum time cost and consumed less power in path planning of mobile using ant colony optimization in a static environment are proposed in [3]. Shortest and collision free route in a grid network for robot path planning using ant colony optimization algorithm are proposed in [4]. Modified Ant colony optimization which are useful to route the robots in robot colony system in offline mode and Node Connectivity Database to check the connectivity of one node with another node while moving are proposed in [5]. A novel and effective robot navigation algorithm for dynamic unknown environments based on an improved ant-based algorithm and two bidirectional groups of scout ants cooperate with each other to find a local optimal static navigation path within the visual domain of the robot are proposed in [6]. SACO (Simple Ant Colony Optimization) and ACO-MH (Ant Colony Optimization Meta Heuristic) gives the collision free optimal path in a grid based environment which are presented in [7]. A new hybrid method for path planning of mobile robot which it employs ACO and Artificial Potential Field as global path planning and local path planning respectively are presented in [9]. New an efficient hybrid ACO-GA approach to solve the path planning problem in static environment by improving the version of ant colony optimization and enhances the solution through a mutation and a modified crossover operator using Genetic Algorithms are presented in [15]. Mobile robot motion is controlled using ant colony algorithm in different four variety of obstacles and search the optimization path in collision free space are presented in [17]. A new method name SACOdm(Simple Ant Colony Optimization) where d stands for distance and m stands for memory is presented in [20],the decision making process is influenced by the existing distance between the source and destination moreover the ants can remember the visited nodes. The selection of optimal path is done by Fuzzy Inference System which is adjusted using a Simple Tuning Algorithm. It is applicable in both the static and dynamic obstacles avoidance.

Meta Heuristic algorithms have many draw-backs as we had find from the literature sur-vey of different researches paper. This work present a new proposal to solve the problem of path planning for mobile robot; it is based in Ant Colony Optimization and Genetic Algorithm. The former search the multiple paths by dropping the pheromones and followed the path which have the more density. The later optimized the optimal path from the multiple path to make the collision free path from both the static and dynamic environments.

This paper is organized as follow, Section 2 describes about Ant Colony Optimization, Section 3 describes about Genetic Algorithm, Section 4 explain about the ACO-GA Hybrid method, Section 5 shows the result of simulation of different methods in different environment. And the last Section 6 gives conclusion and discussion of the work.

2. ANT COLONY OPTIMIZATION

The ant colony system was developed by Marco Dorigo and his colleagues in 1990. It is influenced by the behavior of ants to find the motion path from theirs colonies to the food sources. While moving ants dropped pheromone in ground around from tail. A pheromone is a chemical that simulates a natural behavioral response to the other ant group. The subsequent ants will follow the path based on the amount of pheromone density on all the possible paths between the starting points to the food source. The shortest path is the greater intensity of its pheromone trail and vice-versa. The probability of ants to move from the starting point to food source is given by:

$$P_{ij}^{k} = \frac{\tau_{ij}^{\alpha} \,.\, \eta_{ij}^{\beta}}{\sum \tau_{ij}^{\alpha} \,.\, \eta_{ij}^{\beta}}$$

where, P_{ij}^{k} is the probability for ant k to move from i to j in the next step.
And α and β are the control importance of pheromone τ vs. heuristic value η.

Standard heuristic is given by

$$\eta_{ij} = \frac{1}{d_{ij}}$$

where, d_{ij} is the distance between i and j.

Pheromone update for all ants that have built a solution in that iteration is given by:

$$\tau_{ij} = (1-\rho).\tau_{ij} + \sum_{k=1}^{m} \Delta\tau_{ij}^{k}$$

where, ρ is the evaporation rate and $\Delta\tau_{ij}^{k}$ is the quantity of pheromone laid on edge (ij) with

$$\Delta\tau_{ij}^{k} = \frac{Q}{L_k}$$

where, Q is a constant and L_k is the total length of the tour of ant k.

Algorithm 1: Ant Colony Optimization
Step 1: Initialize parameters
Step 2: Generate starting point and target point.
Step 3: Apply state transition rules.
Step 4: Move to the next node.
Step 5: Evaluate the fitness value
Step 6: Apply local updating rules.
Step 7: Apply global updating rules.
Step 8: Check for convergence condition.

Step 9: If condition is not satisfied then goto Step 2.

Figure 1 shows the path find by ACO in grid environment.

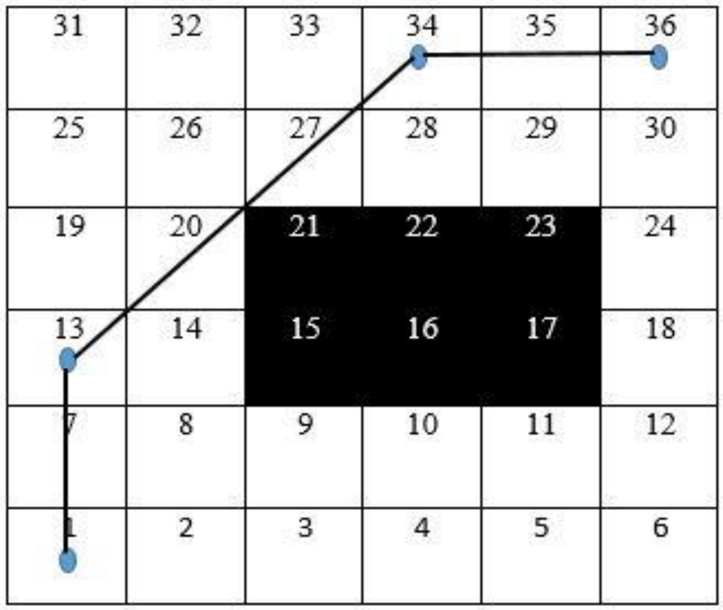

Figure 1 Path find by ACO in grid environment.

3. GENETIC ALGORITHM

The path planning of mobile robot using genetic algorithm is done by many researchers which it will optimized the path in different environments. Here, we will consider the static environment with different obstacles. We have developed genetic algorithm in a conventional way for path planning of mobile robot.

Algorithm 2: Genetic Algorithm
Step 1: Initialize the population.
Step 2: Encoded the chromosomes by integer encoding method.
Step 3: Define the fitness function.
Step 4: Select the best chromosomes by using Roulette wheel selection.
Step 5: Perform the two way crossover operator.
Step 6: Perform the three way point mutation operator.
Step 7: Check the terminal condition and repeat the step 2 to 6 until the condition satisfied.

3.1. Representation of Environment

Environments are considered of 10 × 10 grids sized. The shaded portions are considered as obstacles and white portions are free path. The free paths are considered as feasible points and the obstacles are considered as infeasible points. The obstacles are in rectangular shape of different sizes. Feasible point are considered as free nodes whereas obstacles occupied nodes are considered as infeasible nodes. For the reference we have considered the environment which is showed in Figure 1. Robot are considered of point sized and move with constant speed. Environment is of 2-D workspace. Encoding of the chromosomes are done with the integer based encoding method along with fixed path length as it is more stable than any other methods. In Figure 2, path is

encoded as (0, 33, 63, 74, 77, 99). A chromosomes rep-resent the single solution of a path planning problem and each nodes are the genes of the chromosome. Chromosome consists of starting and target nodes which the robot moves.

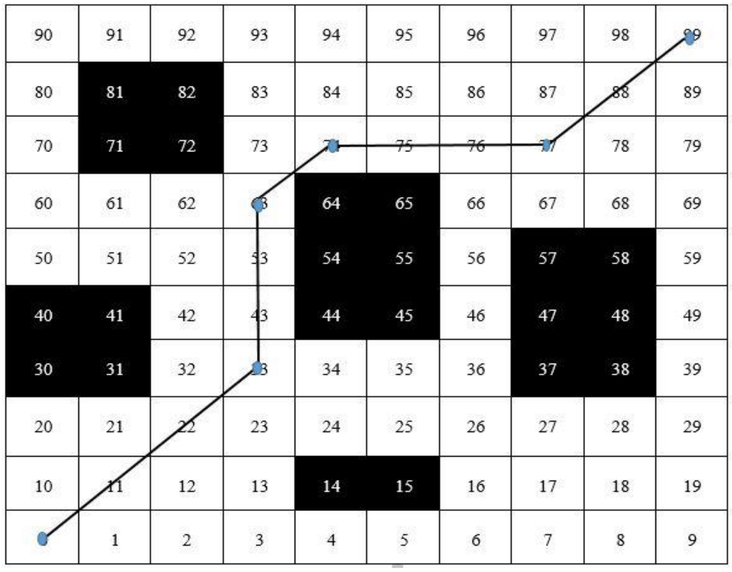

Figure 2 Representation of obstacles and free path in a grid environment.

3.2. Initialization of Population

The initial population of n size can be represented as

$$\text{Initial Population} = < P1, P2, P3\ldots\ldots,P_n >$$

Each structure pi is an integer string of length L in general and it represent a vector of node numbers in the grid which can take values of 1,2,........,L. Normally, Genetic algorithm individuals can contains any point value between starting and targeting point. Thus, the individual generated by genetic algorithm is in the form of:

$$< C_{start}, C1, C2, C3,\ldots\ldots,C_{target} >$$

3.3. Fitness Function

It represents an important part in any evolutionary process of genetic algorithm. Proper selection of fitness function leads to the optimal solution which in ours case it is the shortest path between starting and target point. The fitness function of the complete path is given as

$$Pi = D0 + D1 + D2 + \ldots\ldots + Dn$$

where,

D0 = distance between C_{start} and C1.

D1 = distance between C1 and C2.

D2 = distance between C2 and C3.

D_n = distance between Cn and C_{target}.

The distance between the points is calculated by the (X, Y) coordinates of each point. The distance is formulated as

$$D_i = \sqrt{(X_{i+1} - X_i)^2 + (Y_{i+1} - Y_i)^2}$$

where,

(X_{i+1}, Y_{i+1}) and (X_i, Y_i) are the coordinates of the robot in previous position and current position respectively.

3.4. Selection Operator

Many selection operators are there in genetic algorithm but we are using roulette wheel selection as the probability of selecting individuals is directly proportional to the individual's fitness.

3.5. Crossover Operator

Two point crossover method is used to create offspring's. In this method, two genes are considered randomly from each parents and exchanged there genes. After the operation genes will be sorted and if there is same gene then it will be deleted and randomly generate the new path. Figure 3 shows the two way point crossover operator.

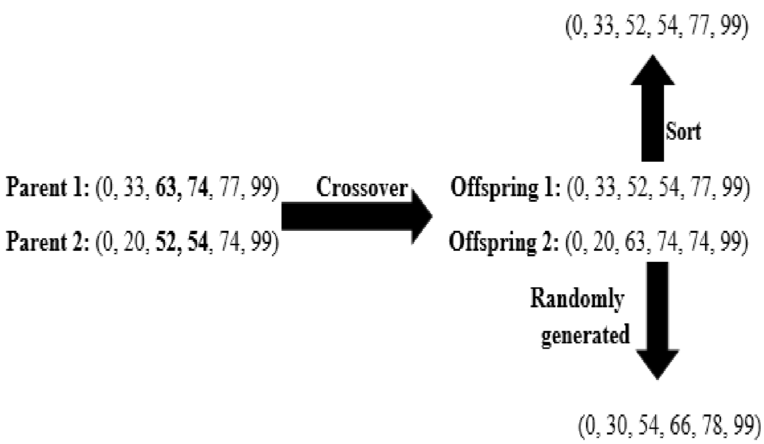

Figure 3 Crossover Operator

3.6. Mutation Operator

Mutation is used to maintain the genetic diversity of population and avoid premature convergence. Three-way point mutation is used in our work as it is more stable than the single point mutation. After that two neighbors nodes of mutated node will gets its fitness value from its neighbors and selected node. From the fitness value, new path way will be guaranteed that it will give the best path way. This function can avoid the maximum obstacles and minimum computing time. Figure 4 shows the three way point mutation operator.

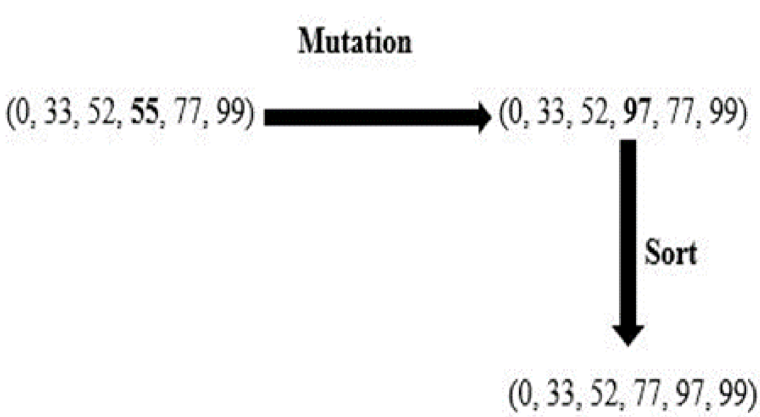

Figure 4 Three-way point mutation.

4. ACO- GA HYBRID METHOD

We have proposed a novel method which is the hybrid method of ACO and GA. Ant Colony Optimization method will find a set of free paths from the environment and paths will be optimized by genetic algorithm to get the optimal solution of path planning problem. Ant colony system find the path by dropping of pheromones and each pheromones will be updated. This method will focus on the minimum path distance with obstacles avoidance. Ants will focused on more pheromones density dropped by the existing ants and path will keep changing according to the density of pheromones. All the paths will be considered for the initial population for optimization by genetic algorithm. After initialization of population it will be encoded by integer encoding method with fixed path length.

Algorithm 3: ACO-GA Hybrid Algorithm
Step 1: Initialize the parameters, starting and targeted nodes.
Step 2: Applying state transition rules.
Step 3: Updates local and global pheromones rules.
Step 4: Check for convergence condition.
Step 5: Collect the set of nodes and initialize the population.
Step 6: Encoded the nodes with integer encoding method.
Step 7: Select the best node by using roulette wheel selection method by reference of fitness function.
Step 8: Perform crossover and mutation operator by using two way point meth-od and three way point method respectively.
Step 9: Check the terminal condition and else repeat step 5 to 8.

Fitness function are designed in order to find the minimum path among different paths. It will select the best path among all existing paths. The cost of the path will be calculated by the function and selection will be done by roulette wheel selection method.

Crossover operator will give the two off-spring's from two parents, from that it will choose the better offspring after sorting of chromosomes. The selected chromosomes will be mutated by three way point mutation method. Whenever there is an obstacles in the path, the last node will find the best fit-ness value surrounding from it which are feasible nodes. The illustrated examples is showed in Figure 5.

The proposed method in this paper is different from others existing methods. The optimized path generated by ACO-GA hybrid method is the optimal path of given environment. The comparison of three methods are showed in Figure 6.

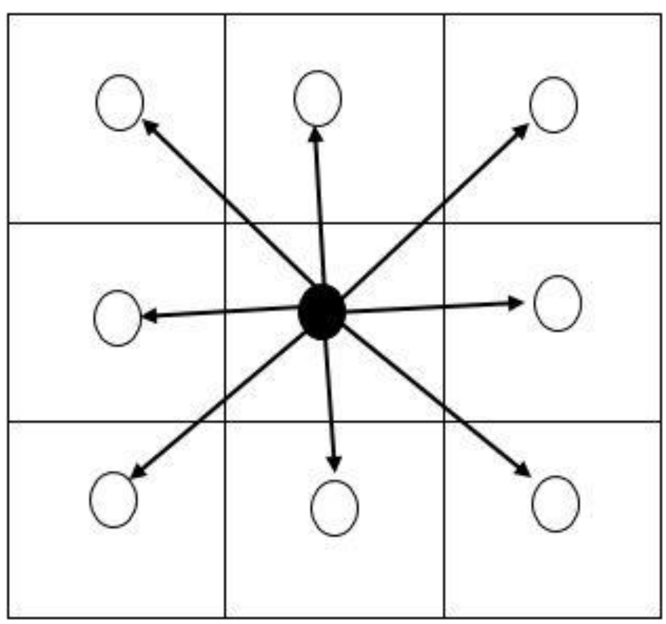

Figure 5 Illustrated examples of eight neighbors of typical node.

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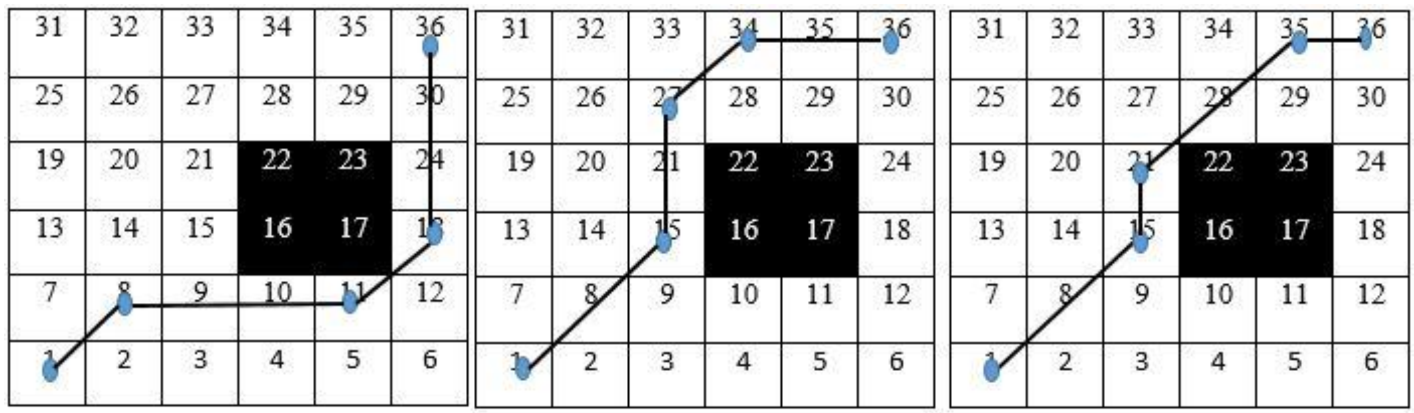

Figure 6 Comparison of path planning methods (a) ACO (b) GA (c) ACO-GA.

5. SIMULATION AND DISCUSSION

The proposed method in this paper is simulated in Microsoft Visual C ++ 6.0 in order to prove the novelty and effectiveness or outperformed from the others existing methods. The parameters used in the proposed method are showed below:

Population size =250, Generation=500, Crossover probability = 1, Mutation rate= 0.1

Pheromone Drop = 0.9, Minimum Pheromone = 0.07, Pheromone factor = 250, Vap factor = 0.992, Ant size = 1.

The simulation are done with three different environments of 16 × 16 grids for each environment and the robot is considered to be point size.

The first environment which is showed in Figure 7 is of three obstacles which occupied of 44 grids and the remaining are feasible nodes i.e. free spaces. The starting coordinates of the mobile robot is (0, 0) and targeted node is (15, 15), the proposed method will find optimal solution in 100 trails and time consumption is 1.8 second which is lesser than other two state of arts.

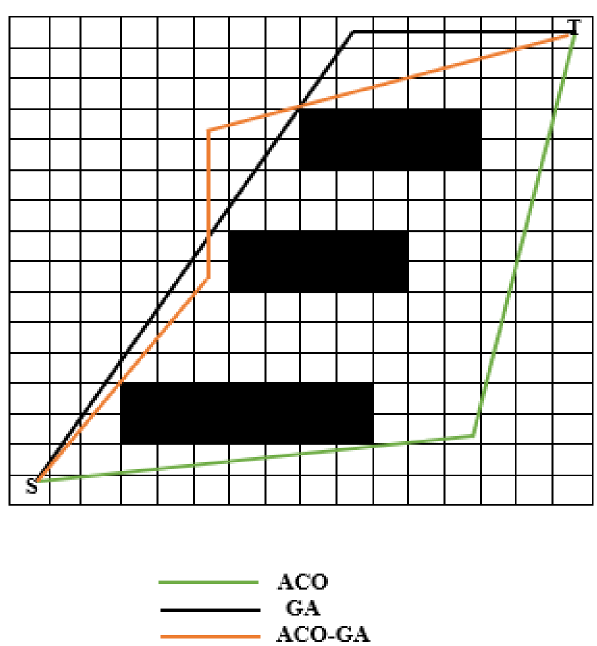

Figure 7 Referenced environment 1

Table 1 Comparison of experimental result of Referenced environment 1

Method	No. of Trails	Bending Energy (J)	Path Length (m)	Solution Time (s)
ACO	72	76	23.4	3.4
GA	83	68	21.7	2.3
ACO-GA	100	53	19.2	1.8

Table 2 Comparison of experimental result of Referenced environment 2

Method	No. of Trails	Bending Energy (J)	Path Length (m)	Solution Time (s)
ACO	53	87	25.8	4.4
GA	64	76	23.7	3.3
ACO-GA	85	67	20.4	3.0

Table 3 Comparison of Experimental result in Referenced 3

Method	No. of Trails	Bending Energy (J)	Path Length (m)	Solution Time (s)
ACO	42	97	28.6	6.4
GA	57	84	26.4	5.1
ACO-GA	79	78	23.8	4.2

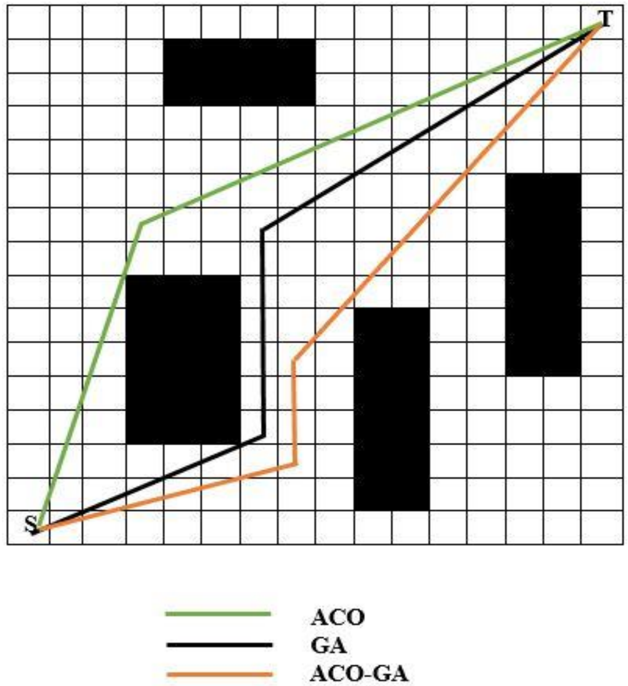

Figure 8 Referenced environment 2

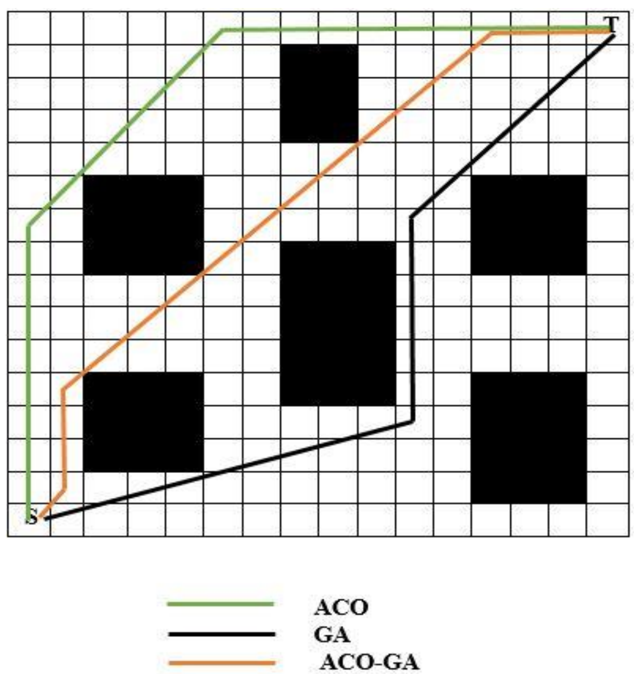

Figure 9 Referenced Environment 3

Table 1 gives the comparison of proposed method with two state of arts based on referenced environment 1. Bending energy, Path length and solution time are calculated in terms of Joule (J), Meter (m) and Second (s) respectively. The second environment

which is showed in Figure 8 is of four obstacles which occupied 47 grids and the remaining are feasible nodes i.e. free nodes. The starting coordinates is (0, 0) and the targeting node is (15, 15), the proposed method will find optimal solution in 85 trails and time consumption is 3.0 second which is lesser than the others state of arts. Table 2 gives the comparison of proposed method with others two state of arts based on referenced environment 2. As compared with the others existing methods, bending energy, path length and solution time of proposed method is lesser. The third environment which is showed in Figure 9 is of six obstacles which occupied 60 grids and the remaining grids are feasible nodes i.e. free nodes. The starting coordinates is (0, 0) and the targeting node is (15, 15), the proposed method will find optimal solution in 73 trails as the environment is complex environment and time consumption is 4.2 second which is lesser than others state of arts. Table 3 gives the comparison of proposed method with others state of arts based on referenced environment 3. Simulations results proved that the overall performances of the proposed method from the others two state of arts is improved and efficient in complex environment.

6. CONCLUSION

In this paper, we have proposed a hybrid method of ACO-GA for path planning of mobile robot in a grid environment which is more efficient than ACO and GA. After performing sufficient number of iterations the optimized path is obtained which is more effective for bending energy, path length and solution time. The simulation results show the effective search of optimized path with-out obstacles avoidance in different environments. In future, we want to develop the hybrid method of ACO-GA to be applied in multi robot system and search the optimized path with collision free space.

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